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ABSTRACT

This investigation examined the effectiveness of training Japanese and American children with a visual animation/construction or verbal labelling strategy for solving computerized geometric matrices that were correctly or incorrectly completed and varied in number of elements (1 to 3) and number of transformations (0 to 2). Subjects were 209 Japanese and American second, fifth, and eighth graders from top academic schools. Pretests and posttests measured spatial reasoning. Japanese and American children achieved comparable accuracy rates on the test of 108 geometric matrices, but Japanese children had faster response times. Training effectiveness was mediated by gender. Boys benefitted from visual training and girls from verbal training (both, specifically, on incorrectly completed matrices). Cultural and schooling issues helped explain additional gender differences in the American sample. Both cultural groups exhibited "self-terminating" strategies on certain matrices and similar developmental trends. (Author)

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The Effect of Visual and Verbal Strategies on Children's Solutions of Figural Matrices in Japan and the United States*

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TM 860 165

Abstract

This investigation examined the effectiveness of training Japanese and American children with a visual animation/construction or verbal labelling strategy for solving computerized geometric matrices that were correctly or incorrectly completed and varied in number of elements (1 to 3) and number of transformations (0 to 2). Subjects were 209 Japanese and American second, fifth, and eighth graders from top academic schools. Pretests and posttests measured spatial reasoning. Japanese and American children achieved comparable accuracy rates on the test of 108 geometric matrices, but Japanese children had faster response times. Training effectiveness was mediated by gender. Boys benefitted from visual training and girls from verbal training (both, specifically, on incorrectly completed matrices). Cultural and schooling issues helped explain additional gender differences in the American sample. Both cultural groups exhibited "self-terminating" strategies on certain matrices and similar developmental trends.

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Analogical reasoning, a form of induction, has always been an aspect of intelligence tests and has been considered a central part of Spearman's g (e.g., Cronbach & Snow, 1977; Snow, 1980). Verbal analogies are familiar to us: Birds are to air as fish are to _____? But nonverbal or figural analogies may be less familiar. An example of a figural analogies test is the Raven's Standard Progressive Matrices (Raven, 1956). The Raven's is often described as a "culture fair" intelligence test because the nonlinguistic format presumably allows analogical reasoning to be assessed without reference to a particular language or culture.

This investigation sought to examine cross-cultural differences in solving Raven's-like problems by focusing on cultural constraints of seemingly universal strategies--strategies of visual and verbal reasoning. Countries selected were Japan and the United States because analogical reasoning is part of the procedural knowledge required by schooling in both countries and problem-solving styles appear to differ. Stylistic differences appear in tests of reflectivity-impulsivity (Salkind, Kojima, & Zelniker, 1978), referential communication (Dickson, Miyake, & Muto, 1977; Foorman & Kinoshita, 1983), and locus of control (Bond & Tornatzsky, 1973; Evans, 1981; McGinnies, Nordholm, Ward, & Bhanthumnavin, 1974; Mahler, 1974; Parsons & Schneider, 1974). The Japanese are more reflective, less talkative, and more aligned with the feelings of others and of groups than Americans are. Underlying these stylistic differences are elements of Japanese culture relating to differences in childrearing practices, socialization, and religion and philosophy (see Weisz, Rothbaum, & Blackburn, 1984, for a review of these differences). The central question is the extent to which stylistic differences affect cognitive processing. We hypothesized that cultural style might affect the representation of information as well as the kind of strategy selected in solving figural matrices.

Two elements of Japanese culture that seemed relevant to representation of information and strategy selection in figural matrix problems are sensitivity to visual form and persistence training. Sensitivity to visual form is expressed in the care with which flowers are arranged, tea is served, handwriting is produced, and paper is folded. Persistence training refers to the intense commitment to excellence in the pursuit of a worthwhile skill, whether it be martial arts, flower arrangement, calligraphy, or violin playing. Sensitivity to visual form would appear helpful in analyzing what Sternberg and Rifkin (1979) call perceptually separable versus perceptually integral attributes of figural matrices. Persistence training would appear to promote a strategy of consistent and exhaustive search, thus avoiding what Sternberg and his colleagues call self-terminating strategies (Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979).

Our previous research on figural matrices (Foorman, Sadowski, & Basen, 1985) found that untrained second, fifth, and eighth graders exhibited self-terminating strategies and were differentially affected by perceptually separable versus integral attributes. In the present investigation we developed two training strategies--one that stressed consistent and exhaustive search through verbal reasoning and one that stressed perceptual analysis through visual reasoning. Both strategies were taught with the aid of a microcomputer. Both training programs will briefly be described.

The figural analogies used in the present investigation consisted of a matrix with three rows. The cells in each row contain one to three geometric elements and zero to two transformations. Each of the first two rows are given; that is, their cells consist either of identical elements or else of elements that undergo a regular transformation. The third row is the test case which determines the truth or falsity of the matrix analogy. If it follows from or is consistent with the first two rows, it is true; otherwise, it is false. Figure 1 depicts two of the matrices. At the top is a zero transformation, two element, "true" matrix; at the bottom is a two transformation, three element, "false" matrix. In addition to the circular motion in a plane and expansion in size transformation represented in the bottom matrix, there was one more kind of transformation represented--addition of an element.

Insert Figure 1 about here

In terms of these matrices, visual training uses computer animation to present on the CRT screen what the child must imagine in executing the transformation. This training also requires that the child demonstrate understanding of the relevant transformation by constructing the final cell of the matrix.

Let's take the bottom matrix in Figure 1 as an example. First the child sees the entire matrix displayed (in color) on the screen. Then a ticking sound prompts the child to hit RETURN. Now the first row of the previously displayed matrix appears and a single cell (called the animation cell) appears below the row in the center of the screen. The program then uses inverse video (the black background becomes white and the white lines of the figures become black) to light up each of the three cells in a sequence, from left to right. As a given cell is lit, its contents appear in the animation cell in inverse video. This presentation is intended to set up a correspondence in the subject's mind between the left to right sequence of cells, and the sequence of events in the animation cell. The first display of the three cells goes fairly slowly, so that the subject can appreciate the relationship between the animation and the three cells of the row. The events in the animation cell are then repeated three times, more quickly in this case and without lighting the cells in the displayed row, in order to make the transformations in the cells more obvious to the eye.

During animation, the transformations in a row come to life in a lively way. This form of display is especially useful in making clear the circular motion transformation, which was significantly harder for second and fifth graders than expansion or addition transformations (Foorman et al., 1985).

After seeing the animated display of the top two rows of a given matrix, the subject then demonstrates understanding of the relevant transformation by actually constructing the final cell of the matrix. At this point, the complete matrix is displayed,

except that the transformed figures in the final row are absent in the final cell. The subject then uses the same routines which we used to draw our matrices to fill in the correct figures in the final row. (The size and shape of the figure is controlled by the keyboard, and the objects positioned in the cell, using the Apple game paddles.) When the subject indicates that the drawing process is complete, the computer then compares the drawn cell with the data for a correctly completed cell. If the drawn cell is correct, the subject is informed and shown a copy of the correct final cell. When the construction is complete, the subject is asked to judge the original matrix (which may have an incorrect final cell as in the bottom of Figure 1), and feedback is then given on the answer.

Taken together, the animation phase and the construction phase of visual training draw attention to perceptual arrangements of transforming elements. One could argue that these two phases tap difference processes and, therefore, should be examined separately. Our pilot work suggested, however, that the passive viewing of the animation requires the active execution of the transformation in the third row in order to be interactive like the verbal training. A brief description of verbal training follows.

In contrast to the emphasis on imagining in visual training, the emphasis in verbal training is on discrete propositions. The defining propositions in these matrices are the transformations. Consequently, verbal training consists of naming the transformations and elements in the transformations. As in visual training, the computer first presents the whole matrix for the subject's inspection. Then the first row only is displayed on the screen, and the training questions concerning the changes in that row are printed on the screen. The subject responds to such questions as "Which shape changes in this row?"; "How does it change?"; and "What is another way it changes?" by selecting answers from a menu. Subjects are given immediate feedback on their answers and are prompted to select again until their answer is right. Programmed data on each matrix presented during training determines the sequence of questions appropriate to it. After answering these questions for the first two rows of the matrix, the subject is asked to judge the original matrix and then receives feedback on the answer.

Training subjects to name elements and transformations should encourage a strategy of consistent and exhaustive search. Such a strategy would seem particularly useful in false matrices where the transformation is correctly executed but a nontransforming element is incorrect. Imagine that the circular motion transformation is correctly executed in Figure 1--that the dash has rotated to the top left-hand quadrant rather than the top right-hand quadrant in the bottom right-hand cell. Also, imagine that there is a triangle rather than a diamond in the bottom right-hand cell. Subjects who are attending solely to the two transformations may terminate information search as soon as the correctness of the circular motion and expansion transformation is verified. Such a strategy is similar to Sternberg's notion of "self-termination" (Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979). That is, subjects scan answer options in a top-down fashion until the minimum number of criteria for acceptability are met. Brown and DeLoache (1978) and Siegler (1978) have found that encoding becomes more exhaustive with age. Our study of second, fifth, and eighth graders' strategies for solving figural matrices generally confirm such developmental patterns of exhaustive search (Foorman et al., 1985, Experiement 1). However, self-terminating strategies were evidenced even by eighth graders on some false matrices. Experiment 2 of this same study looked within single element false matrices to locate sources of difficulty affecting strategy selection of fifth graders. Both the kind of transformation and the nature of falseness in the matrix constrained strategy selection. In the case of expansion matrices, self-terminating strategies led to ignoring information beyond the transformation, except

by those high in perceptual abilities as determined by the Figural Intersection Test (Pascual-Leone, 1969) and Children's Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971). In the case of circular motion matrices, strategy selection was more fully exhaustive in that time was taken to process nontransforming elements. But the mapping of the A-B relationship to the B-C relationship was often by associative inferencing or overgeneralized inferencing. Associative inferencing dictated that the correct answer be a duplicate of term B, while overgeneralized inferencing meant that the rotation from B to C moved one quadrant too far. However, in the case of addition matrices, a counting strategy led to successful, although somewhat slow, encoding.

In summary, the present investigation examines across cultures the effect of training in visual and verbal reasoning on figural matrix performance. Specifically, we asked the following four questions: 1) Does training in visual and/or verbal reasoning improve accuracy and latency of figural matrix solution compared to no explicit training? 2) Does national group interact with training effectiveness? Specifically, in a country that values sensitivity to visual form and persistence training, such as Japan, would visual training promote greater accuracy than verbal training, and would response times be slower, indicative of a more reflective problem solving style? And in a country that values verbal fluency and quick action, such as the United States, would verbal training prove more effective than visual training and would response time be quicker, indicative of a more impulsive problem solving style? 3) Would traditional sex difference work to counter national group differences in training effectiveness? That is, would boys in both countries do better with visual training and girls in both countries do better with verbal training (see Maccoby & Jacklin, 1974)? 4) Would training transfer to other perceptual and cognitive measures?

Method

Subjects. Subjects were 103 Japanese second, fifth, and eighth graders from a school in Miyazaki, Japan, and 106 American second, fifth, and eighth graders from a school in Houston, Texas. Both schools were similar in parental SES and entrance requirements and both Miyazaki and Houston represent cities of comparable southern mentalities. Children in both cities were tested at the 3/4 point in the school year and ages were comparable at each grade level (although U.S. second graders were slightly older and there was more variability in age in all U.S. grades). The senior author directed data collection in both countries. In Japan, the second author administered the visual and verbal training and the first author the control condition. In the United States, the first author and her graduate assistants administered the treatments. Experimenter bias across cultures was greatly reduced by virtue of the computerization (and, hence, standardization) of the treatments and the fact that the senior author directed data collection in both countries.

Procedures. As pretests, subjects were administered the Raven's Standard Progressive Matrices, Sets A through E (Raven, 1956), the Figural Intersection Test (Pascual-Leone, 1969), and the Spatial Relations Test (Thurstone & Thurstone, 1949). Then subjects were trained and tested on the computerized figural matrices.

The Figure Intersection Test (FIT) is an untimed, group-administered, paper and pencil test where a subject has to look at a variable number of geometric shapes, physically separated from each other on the right side of the test page, and then find and mark the common area of intersection of these shapes in an overlapping configuration of shapes on the left. There are 43 test items, varying in number of shapes from 2 up to 10, and 6 introductory items. The introductory items demonstrate that shapes can change in size or orientation as they appear in the overlapping configuration on the

left side of the paper and that sometimes the configuration contains an irrelevant shape. In our previous research (Foorman et al., 1985), correlations between the FIT and accuracy on the figural matrices were moderately strong (i.e., $r = .50$, $p < .01$ for eighth graders on false matrices in Experiment 1, and $r = .35$, $p < .05$ for fifth graders on false matrices with expansion transformations in Experiment 2).

The Spatial Relations Test is a group-administered, timed test consisting of 30 problems and six practice problems. Subjects look at the standard figures on the left and decide which of the five figures on the right represents a rotation in a plane of the original figure. To aid task understanding for second graders, the six practice items were reproduced on 12" cards. For the first four practice items an experimenter rotated the card of the standard figure to the right and to the left and asked the students to judge whether each of the five figures on the right were the same as the standard. Students answered the final two practice items by themselves and an experimenter checked their answers. The fact that all second graders in both Japan and the United States got these final two items correct was interpreted as evidence of task understanding.

The geometric matrices were displayed to each subject on an Apple II+ microcomputer and color monitor in two sessions, a training session of 12 matrices and a test session of two random orders of 108 matrices (6 "true" and 6 "false" matrices representing each of the nine item types obtained by crossing 1-3 elements with 0-2 transformations). The 12 training matrices represent one true and one false matrix in the six item types with one and two transformations. At each grade level, for Japanese and American children, subjects were randomly divided into visual training, verbal training, and control groups. The control group was exposed to the same 12 training matrices as the other two groups and were merely given feedback on the accuracy of their problem solution. For the Japanese children, messages in the verbal training were programmed in the Japanese syllabary (i.e., hiragana and katakana). One to three days after a subject had been trained, he or she was administered the 108 test matrices and told to "work as fast and carefully as possible and hit the 'Right' button (on the paddles) if the puzzle is completed correctly and the 'Wrong' button if it isn't, just as we did before." Within a day or two of solving the 108 matrices, each subject was individually readministered the FIT and Spatial Relations Test.

Results

Two (country) x 2 (sex) x 3 (grade) x 3 (training) x 3 (number of transformations) x 3 (number of elements) multivarate analyses of variance with repeated measures on levels of transformations and levels of elements were performed on number of correct responses and on mean correct and incorrect response time for true and for false matrices separately. Results are presented in terms of averaged significance tests using sequential sums of squares. Posttest comparisons used Fisher's LSD because of the large number of means being compared. Due to the liberalness of this test, an alpha level of .01 was used. Separate analyses for true and false matrices were conducted because processing demands and, presumably, strategies for solution are quite different (Mulholland, Pellegrino, & Glaser, 1980; Pellegrino & Glaser, 1982). For example, in contrast to true matrices, processing of false matrices can be terminated immediately at the point where incorrect information is discovered. Response times which were more than two standard deviations above or below the mean of a subject's response time for each item type were eliminated. Eliminations never exceeded six percent of the responses on an item type for any grade. In the analyses of accuracy, the actual response variable was the proportion of correct choices out of six possible in each item type. Because of the inherent relationship between means and variance

in proportional data, an arcsine transformation was applied to the data before the analysis was performed. Mean numbers correct and mean response time on true and false item types are presented in Tables 1, 2, 3, and 4.

Insert Tables 1-4 about here

Analyses of Variance on Accuracy and Response Time

True matrices. The analysis of number of correct responses on true matrices yielded a main effect of Grade, $F(2, 173) = 34.38$, $p < .001$ and the following interactions: Grade x Transformations, $F(4, 346) = 7.73$, $p < .001$; Grade x Transformation x sex, $F(4, 346) = 3.08$, $p < .02$; and Transformation x Element, $F(4, 692) = 6.39$, $p < .001$. Posttest comparisons indicated that the grade effect was due primarily to the lower accuracy scores by second graders. The interaction with sex appears to be caused by the fact that boys did not show significant decreases in accuracy as the number of transformations went from zero to two but the second grade girls did. In particular, the second grade girls had significantly lower scores for one transformation than for none and significantly lower scores for two transformations than for one. At no point, however, did girls score significantly lower than boys of equal grade when there were the same number of transformations.

Posttest comparisons of the significant Transformation x Element interaction led to the conclusion that with zero transformation, three elements were significantly more difficult than one or two. With one transformation, three elements were more difficult than two and two were more difficult than one. But with two transformations, two or three elements were not different from each other but were both significantly lower than for one element. Oddly enough, one transformation with three elements had a significantly lower mean accuracy rate than any other combination. But, Table 1 shows this phenomenon occurring primarily in the second grade, with older subjects scoring close to ceiling.

In the analysis of response times for true matrices, there was a main effect of Country ($F(1, 173) = 35.12$, $p < .001$) as well as a main effect of Grade, $F(2, 173) = 5.26$, $p < .01$. Significant interactions between subjects were: Country x Grade, $F(2, 173) = 4.08$, $p < .05$; and Grade x Training, $F(4, 173) = 2.56$, $p < .05$. Within subjects, both Transformations and Elements were significant, $F(2, 346) = 8.73$ and 384.18, $p < .001$, respectively. Significant interactions were: Grade x Transformations, $F(4, 346) = 6.73$, $p < .001$; Country x Element, $F(2, 346) = 11.57$, $p < .001$; Grade x Element, $F(4, 346) = 7.97$, $p < .001$; Country x Grade x Element, $F(4, 346) = 2.68$, $p < .05$; and Transformations x Element, $F(4, 692) = 38.74$, $p < .001$.

Japanese children responded more quickly to true matrices than American children did. However, across grades, patterns of responses differed for the two national groups. For Japanese children response time decreased across grades. For American children, the pattern was an inverted U: fifth graders were significantly slower than second or eighth graders. Moreover, posttest comparisons for interactions of Country with Elements and with Transformations indicated that differences in response times between countries was small (although significant) for the easier matrices but as the matrices became more difficult, the difference between countries increased.

Lastly, the effect due to adding elements to the matrices depended on how many transformations were present. With zero transformations, going from one element to two produced a smaller increase (.68 sec.) than going from two to three elements (1.77 secs.). With one transformation, the increase from one to two or two to three elements had the same effect on response time (adding about 2.4 secs.). With two transformations, going from one to two elements increased response time by 2 sec. but going from two to three elements increased response time by only .84 sec. In other words, for both Japanese and American children, the addition of a third element to two transformation true matrices did not result in much increase in processing time. We see from Table 1 that near ceiling accuracy was maintained for the older subjects while for second graders, faster times meant more errors.

False matrices. The analysis of number of correct responses on false matrices revealed main effects of: Grade, $F(2, 173) = 33.62$, $p < .001$; Transformations, $F(2, 346) = 78.60$, $p < .001$; and Elements, $F(2, 346) = 88.90$, $p < .001$. The following interactions were significant: Grade x Transformation, $F(4, 346) = 8.40$, $p < .001$; Transformation x Element, $F(4, 692) = 12.90$, $p < .001$; Sex x Training x Transformations, $F(4, 346) = 3.90$, $p < .01$; Grade x Sex x Training x Element, $F(8, 346) = 2.70$, $p < .01$; and Grade x Transformation x Element, $F(8, 692) = 4.00$, $p < .001$.

As we look across transformations in Table 3, we see that accuracy decreases as transformations increase from zero to two. But these differences depend on grade level and an interaction of sex with training. Since grade and transformations also interacted with elements, let's consider the Sex x Training x Transformation first. Posttest comparisons indicated that males receiving the visual training did not exhibit a significant decrease in scores as the number of transformations increased but that males receiving the verbal training and those in the control condition did exhibit a significant decrease in scores between zero transformations and two transformations. Females, on the other hand, did not exhibit a significant decrease in scores as the number of transformations increased when they received the verbal training, but did exhibit a significant decrease from zero transformations to two transformations in the visual training group and the control group. Thus, boys showed better accuracy when visually trained and girls showed better accuracy when verbally trained, with respect to transformations in false matrices.

Finally, posttest comparisons helped explain the Grade x Transformation x Element interaction. With zero transformations, fifth and eighth graders were equally accurate and better than second graders, regardless of the number of elements. With one transformation, all grades differed from each other on one and three element matrices, while on two element matrices, just the eighth grade versus second grade comparison was significant. With two transformations, the three grades differed from each other across all numbers of elements. Lastly, looking at Table 3, we conclude that for all grades errors occur with the addition of a third element to zero or one transformations. However, when there are two transformations errors are more apparent with the addition of a second element. Surprisingly, the error rate is greatest for single transformation matrices with three elements.

In the analysis of response times for false matrices, there were significant main effects of: Country, $F(1, 173) = 34.12$, $p < .001$; Sex, $F(1, 173) = 7.15$, $p < .01$; Transformations, $F(2, 346) = 406.47$, $p < .001$; and Elements, $F(2, 346) = 580.20$, $p < .001$. Significant two-way interactions were: Grade x Training, $F(4, 173) = 3.72$, $p < .01$; Grade x Transformations, $F(4, 346) = 15.20$, $p < .001$; Country x Transformation, $F(2, 346) = 65.5$, $p < .001$; Grade x Element, $F(4, 346) = 6.10$, $p < .001$; Country x Element, $F(2, 346) = 13.20$, $p < .001$; and Transformation x Element, $F(4, 692) = 48.90$, $p < .001$.

Significant three-way interactions were: Grade x Training X Transformations, $F(8, 346) = 3.20$, $p < .01$; Grade x Training x Elements, $F(8, 346) = 3.0$, $p < .001$; Country x Training x Elements; $F(4, 346) = 3.60$, $p < .01$; and Grade x Transformations x Elements, $F(8, 692) = 3.60$, $p < .001$. Finally, there was also a significant interaction of Country x Sex x Transformations x Elements, $F(4, 692) = 3.50$, $p < .01$.

As in the analyses of true matrices, Japanese children are faster than American children in their responses on false matrices, particularly as matrices increase in complexity (i.e., numbers of transformations and numbers of elements increase). The two countries also differed in the way that training and sex affected latencies as matrices increased in complexity. Posttest comparisons on the Country x Training x Element interaction showed no significant effect of training for Americans--all training conditions showed similarly significant increases in response time as number of elements increased. However, for the Japanese children, visual training resulted in significantly faster times for two and three element matrices. Moreover, for Japanese children, verbal training as well as visual training resulted in insignificantly different latencies between one and two element matrices.

Finally, gender differences varied in the two countries as matrices increased in complexity. The Country x Sex x Transformation x Element interaction appears to result from the fact that for simple matrices, zero transformations with one, two, or three elements, and single transformations with one or two elements, there were no differences between sexes within country (although countries differed). However, for more complex matrices (i.e., one transformation, three element matrices, and all two transformation matrices) American boys responded more quickly than American girls, while in Japan, boys and girls did not differ.

Posttest comparisons on the Grade x Training interaction with Transformations and also with Elements revealed similar results: visually trained fifth graders responded faster to more complex matrices (i.e., matrices with one and two transformations and those with two or three elements) than verbally trained or control subjects. The previous analysis of accuracy on these matrices pointed out that visual training helped boys maintain accuracy as matrices increased in complexity. Thus, at least for fifth grade boys, visual training promoted quick and relatively accurate responses. In the case of second graders, however, faster response times as matrices increased in complexity were associated with significantly more errors, regardless of training condition.

Effect of Matrix Characteristics

Additional multivariate analyses of variance were conducted to examine the consequences of particular kinds of transformations--circular motion in a plane (rotation), expansion in size (expansion), or addition of a form (addition). Both accuracy and response time were analyzed for both true and false matrices, rotation, addition, and expansion transformations, and two and three element matrices. The between subjects variables were country, grade, sex, and training group. Single element matrices were eliminated in order to keep the number of matrices equal for each combination of within subjects factors. In order to see how each kind of transformation affected matrix performance, analyses were only done for single transformation matrices. Since only two matrices were available for each crossed condition, no transformation of the accuracy data was performed.

In the analysis of accuracy, there was an interaction of Type of Matrix with Kinds of Transformations, $F(2, 346) = 4998.36$, $p < .001$. Briefly, for both American and

Japanese children, rotations in true matrices were significantly more difficult than either additions or expansions, but additions and expansions did not differ from each other. On the false matrices, rotations were significantly harder than additions which were significantly harder than expansions for both countries.

There was also a significant interaction of Country x Sex x Element x Kind of Transformation, $F(2, 346) = 4.15$, $p < .05$. This interaction revealed that Japanese girls were consistently more accurate than Japanese boys across all kinds of transformations while American girls were consistently less accurate than American boys across these matrices. However, the only significant sex difference was between American boys and girls, with girls scoring significantly lower on three element rotations than boys.

In addition to the preceding analysis, an analysis of covariance using the Spatial Relations pretest as a constant covariate was done. The results indicated that the spatial pretest was significantly related across matrices to accuracy, $F(1, 172) = 15.29$, $p < .001$. While controlling for the covariate reduced the significance of Grade to accuracy, it remained marginally significant, $F(2, 172) = 3.61$, $p < .05$.

Finally, in analyzing response time with respect to kinds of transformations, the interaction of Country x Training x Elements x Kinds of Transformation is noteworthy, $F(4, 346) = 3.79$, $p < .01$. Posttest comparisons indicated that visually trained Japanese children responded faster than visually trained Americans for every kind of transformation. Verbally trained Japanese were also faster on three element matrices than verbally trained Americans. Also, the significant Country x Grade x Type of Matrix x Kind of Transformation interaction, $F(4, 346) = 4.92$, $p < .01$, was interesting in that grade patterns of response times differed between countries on true rotation transformations. In Japan the significant increase in time occurred between fifth and eighth grade while in the United States it was between second and fifth grade.

Analyses of Perceptual and Reasoning Tests

The Raven's Progressive Matrices were administered to check on comparability in basic reasoning abilities across the two national groups. A 2(country) x 2(sex) x 3(grade) x 3(training) analysis of variance on Raven's scores revealed no significant differences due to country or training and significant differences due to grade and sex. The significant main effect of sex, $F(1, 6) = 5.68$, $p < .05$, was due to males' higher scores.

To see if training on these figural matrices transferred to other perceptual and reasoning tasks, 2(country) x 2(sex) x 3(grade) x 3(training) analyses of variance with repeated measures were performed on FIT and Spatial Relation's pre- and posttest scores. Means for these measures are presented in Table 5.

Insert Table 5 about here

Positive transfer would be signaled by significant interaction of pretest and posttest trials with training, where verbal and/or perceptual group showed gains and controls did not. No such evidence of positive transfer was seen. The only significant effect of training was in an interaction with Country for Spatial Relations, $F(2, 173) = 3.70$, $p < .05$. We can see from Table 5 that this effect was due to differing patterns of

scores for the training groups in the two countries. A post hoc Scheffe test (alpha = .05) indicates that Spatial Relation's scores were lowest in the verbal training group in Japan and highest in that same group in the United States. Country also interacted significantly with Grade and with Trials, $F(2,173) = 6.21$, $p < .01$. We can see from the pretest means that the American second and fifth graders out-performed the Japanese children at these grade levels but that in the eighth grade, Japanese scores were higher. The younger Japanese children showed notable improvement in the posttest. Finally, there was a significant main effect of sex, $F(1,173) = 30.06$, $p < .001$. Boys' Spatial Relation's scores were higher than girls.

Training was not significant in the analysis of FIT scores either. There was a main effect of Country, $F(1,173) = 24.21$, $p < .001$, favoring the Japanese. But the significant interaction of Grade with Country, $F(2,173) = 7.00$, $p < .01$, indicates comparability for the two countries in the fifth grade. Additionally, the significant interactions of Trials with Country, $F(1,173) = 7.01$, $p < .01$, appears to be due to the greater gains in FIT scores made by the American children. However, notice that the Japanese eighth graders were essentially performing at ceiling.

In order to examine relationships between these measures of spatial and reasoning abilities and matrix performance, intercorrelations were performed on scores on the Ravens, FIT, and Spatial Relations pretest and posttest, and number correct on true and false matrices for males and females within each grade.

Insert Table 6 about here

From Table 6 we see that the Raven's correlates significantly with total number correct on true and false matrices for males and the strength of the relationship increases with development--$r = .46$ and .43, $p < .01$ for second grade; $r = .57$ and .58, $p < .001$ for fifth grade; and $r = .65$ and .57, $p < .001$ for eighth grade, respectively. Significant correlations for accuracy on true and false matrices and the FIT range from weak to moderate in the second and eighth grades (i.e., $r = .29$, $p < .05$ to $r = .50$, $p < .001$) for both males and females. These correlations are stronger (i.e., $r = .40$ to .61, $p < .001$) for the males in the fifth grade. Significant correlations between Spatial Relations and accuracy on the figural matrices are moderate (i.e., $r = .34$, $p < .05$ to $r = .55$, $p < .001$) for males in second and fifth grades. In eighth grade, the relationships weaken slightly and females enter the picture. Correlations between Spatial Relations and FIT pretests are $r = .36$, $p < .01$ and $r = .45$, $p < .001$ for fifth and eighth grade males and $r = .46$, $p < .001$ for eighth grade females. Correlations between Spatial Relations and FIT posttests are weaker: $r = .29$ and .31, $p < .05$ for second and fifth grade females, and $r = .38$ and .33, $p < .05$ for fifth and eighth grade males.

Discussion

In this investigation we examined effectiveness of training on computerized figural matrix problems within and across cultures. Training took the form of verbally labelling elements and transformations or visually constructing transformations. Questions were raised concerning the mediating effects of culture and gender on training. For example, would the Japanese culture's sensitivity to visual form and emphasis on persistence and the American culture's valuing of verbal fluency and quick action mean that visual training would be effective for Japanese children and verbal training be effective for

American children? Or would traditional gender differences over-ride culture? That is, would males' spatial ability support effectiveness of visual training in both countries and females' verbal ability support effectiveness of verbal training in both countries?

Results indicate that training effectiveness is mediated by culture and gender, at least for false matrices. For true matrices accuracy rates were near ceiling for older subjects, even without training. Focussing our discussion, then, on false matrices, we are reminded that boys' accuracy improved with visual training and girls' with verbal training as transformations increased in number. And for fifth grade boys who were visually trained, response times were faster as well.

We are also reminded that for Japanese children, visual training prompted faster response times for matrices with several elements and every kind of transformation, and both verbal and visual training made responses on two-element matrices as quick as responses on single-element matrices. Japanese children responded faster than American children overall (on true matrices as well). And as matrices became complex, American boys responded faster than American girls; yet no gender difference emerged in the Japanese latencies. Also, no gender difference was apparent in Japanese children's accuracy on matrices with the most difficult kind of transformation--rotation. But in the American sample, females' accuracy was significantly lower than males' on three-element rotations.

In sum, training did make responses more accurate and, in many cases, faster. But for boys it was visual training that improved accuracy and for girls it was verbal training. Such a finding is consistent with the literature on gender differences (e.g., Maccoby & Jacklin, 1974), but was nonetheless somewhat surprising to us since we had not found gender differences in our previous studies of figural matrix performance (Foorman et al., 1985). However, these previous studies did not involve training and were conducted in a lower middle-class parochial school that included kindergarten through eighth grade. The Japanese and American schools in the present study were the top academic schools in their cities. They included kindergarten through twelfth grades and were divided into lower, middle, and upper units. Entrance into both schools was gained through competitive examinations and parents were typically professional people with high expectations of achievement for their children.

One difference between the schools was that the American school was private and the Japanese school was public (supported by the Prefecture and affiliated with Miyazaki University). It is possible that the American school was inadvertently reinforcing sex-role stereotypes in teaching computer and math-related skills. Girls in the American school often signaled their anxiety about math by asking if the matrices were a math test. No Japanese child ever signaled such anxiety. Achievement in math is serious business for Japanese girls as well as boys for math is one of three required subjects on university entrance examinations. Computer skills, on the other hand, are not part of university entrance exams and are not typically available in Japanese schools or in Japanese homes. Consequently, neither Japanese boys nor girls had much experience with them. The American children, however, all had computers at home. But it was the boys, not the girls, who were playing with them, alongside their fathers.

It is possible that these cross-cultural schooling factors related to computers and math achievement combined with more traditional cultural elements to produce response time differences. The faster Japanese response times on true and false matrices (especially as they increased in complexity) are consistent with the notion of persistence training. The testing environments in the two countries were similar: several computers operating in moderate-sized rooms with minimum distractions. The Japanese children,

dressed in their black uniforms, sat upright, eyes fixed on the computer screen. American children, on the other hand, were casual in dress and posture, and often averted their gaze from the screen.

It is important to remember that our method of removing "outliers" from individuals' response time resulted in comparable elimination (i.e., 6%) for both countries and testing instructions were standardized by computer presentation. Thus, these response time differences are real. But without corresponding differences in accuracy, what do they mean? Before one could comfortably answer such a question, replication would be required where stress was put on the "as fast" in the instructions "as fast and as carefully as you can." Both groups of children knew they were part of a cross-national study, but perhaps the Japanese children were responding to this competitive challenge by concentrating their full attention on the task and, consequently, increasing task tempo. We must also remember that Japanese scores on the Figural Intersection Test were significantly higher than American scores on pre- and posttests. A high concentration factor is required in this test as one methodically searches for the common area of intersection of two to ten overlapping shapes.

Since accuracy rates did not vary across cultures, these differences in response times on figural matrices do not necessarily indicate differences in information processing. In fact, inferences regarding strategy suggest great similarities between Japanese and American children. First, accuracy on false matrices was much worse than accuracy on true matrices, especially when falseness lay in non-transforming elements. Thus, subjects apparently interpreted instructions to "look to see what's happening" as a mandate to execute the transformation, if it executes correctly then say "Correct" and terminate information search.

Evidence for such a self-terminating strategy comes from the relatively high accuracy on true matrices and on false matrices with incorrect transformations and relatively low accuracy on false matrices with correct transformations. We examined accuracy rates on the four false matrices (in two random orders) which had single, correct transformations and an incorrect nontransforming element. Of these four, the matrix with an expansion transformation and single element had high accuracy rates. Of the remaining three, the one with an addition transformation and two elements had high accuracy rates for older subjects. The remaining two were rotation matrices, one with two elements, the other with three. Accuracy rates were at chance level or lower for second and fifth graders (i.e., 20%-50%) and around 80% for eighth grade controls. Response times for these two matrices were <u>not</u> correspondingly slower.

We had hoped that our verbal training would promote a strategy of consistent and exhaustive search, thus eliminating premature termination. Perhaps such a goal could be achieved if verbal training required <u>all</u> elements to be labeled in a matrix, not just the one in the transformation. Such a change was considered and rejected during piloting of the software when we saw how lengthy and tedious verbal training became for the younger children.

Furthermore, we had hoped our visual training would encourage fast and accurate encoding of a conceptually difficult transformation--rotations. We appear to be more successful in this endeavor. Visual training promoted accuracy for boys on <u>all</u> transformations, including rotations, and faster responses for Japanese boys and girls (without a loss of accuracy). Also, it is important to note that visual training resulted in more correct judgments on the twelve training matrices than verbal training which, in turn, resulted in more correct judgments than the control condition, $\underline{F}(2, 6) = 13.54$, $\underline{p} < .001$. Errors during the construction phase of visual training primarily involved

rotations (i.e., 50% errors on rotations compared to 14% on addition and 1% on expansion for both national groups). Rotation errors tended to occur when an element was placed in the same position as in the adjacent left cell (i.e., no rotation--an associative strategy) or in the same position as in the original matrix (i.e., one too many rotations--a memory strategy or overgeneralization). Second graders in both countries were more likely to make the first error and fifth graders the second.

The fact that visual and verbal training did not transfer to improved performance (beyond that of the control group) on the posttest measure of perceptual and reasoning ability is disappointing but not surprising. Thirty minutes of training is woefully inadequate for such transfer, especially when pretest gender differencnes are considered.

In conclusion, computerized visual and verbal training of the sort provided in this investigation provide promise for improving figural matrix performance across countries as diverse as the United States and Japan. The animation and construction experience of visual training seems to help represent to young children the conceptually complex rotation transformation and to help boys improve accuracy (and sometimes speed) on all transformations. Verbal training, on the other hand, appears to "fit" with girls' strategies, for training in labelling elements and transformations improved their accuracy. But our cross-cultural design helps prevent us from concluding on the basis of the American gender differences in accuracy on complex rotation matrices that girls are inherently poor at spatial representation. Japanese girls scored higher (though nonsignificantly so) on these complex rotations than Japanese boys. And visual training boosted response times for Japanese girls just as it did for boys. We are left, then, with an appreciation for the impact of schooling and culture on something as universally construed as analogical reasoning. Such affective factors as computer and math anxiety and differential expectations of math achievement may indeed culturally constrain American girls, while such cultural elements as persistence training and sensitivity to visual form may, in fact, boost achievement for Japanese girls.

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TABLE 1

Mean Number of Correct Responses

on True Matrices

Grade/ Sex	Zero Transformations				One Transformation				Two Transformations			
	1E	2E	3E	Mean	1E	2E	3E	Mean	1E	2E	3E	Mean
Second												
Male	.86	.88	.93	.89	.89	.91	.86	.89	.86	.78	.85	.83
Female	.95	.93	.94	.94	.90	.88	.84	.87	.82	.75	.79	.79
Total				.91				.88				.81
Fifth												
Male	.97	.98	.97	.97	.96	.95	.94	.95	.94	.90	.94	.93
Female	.97	.98	.98	.98	.96	.96	.95	.96	.94	.93	.96	.94
Total				.97								
Eighth												
Male	.99	1.00	1.00	.99	.99	.97	.98	.98	.98	.97	.98	.98
Female	.98	.99	.99	.99	.98	.99	.99	.99	.99	.96	.98	.97
Total				.99				.98				.98

NOTE: E - Element

Table 2

True Matrices Response Times

Grade/ Training	Zero Transformations							One Transformation							Two Transformations						
	1E		2E		3E			1E		2E		3E			1E		2E		3E		
	J	US	J	US	J	US	Mean	J	US	J	US	J	US	Mean	J	US	J	US	J	US	Mean
Second																					
Visual	3.68	5.44	4.43	5.51	5.19	7.88	5.35	4.51	5.80	5.43	7.58	7.18	11.04	6.92	6.51	9.09	6.97	9.74	7.60	11.55	8.58
Verbal	4.02	4.09	4.39	4.96	5.62	6.14	4.87	4.13	5.01	6.01	7.40	7.81	9.94	6.72	6.29	7.76	7.41	9.54	7.35	9.81	8.03
Control	4.23	6.07	4.15	4.98	5.70	7.23	5.39	4.13	5.58	6.81	9.77	7.54	9.41	7.21	6.24	7.58	7.00	8.66	8.07	9.26	7.80
Total	3.98	5.20	4.32	5.15	5.50	7.08		4.26	5.46	6.08	8.25	7.51	10.13		6.35	8.14	7.13	9.31	7.67	10.21	
Fifth																					
Visual	3.67	4.74	3.76	6.05	4.84	7.77	5.14	3.38	5.64	4.86	7.94	5.84	11.45	6.52	5.39	4.43	5.62	11.20	6.61	12.73	7.66
Verbal	4.38	5.83	5.61	5.97	6.60	10.27	6.44	4.74	7.14	7.30	9.49	9.63	13.64	8.66	7.36	10.43	9.57	11.96	10.72	14.33	10.73
Control	4.38	4.89	5.12	6.14	7.18	8.75	6.08	5.60	6.02	7.64	9.33	9.17	13.81	8.59	7.12	9.25	11.81	12.86	10.44	13.01	10.75
Total	4.14	5.15	4.83	6.05	6.21	8.93		4.57	6.27	6.60	8.92	8.21	12.97		6.62	8.04	9.00	12.01	9.26	13.36	
Eighth																					
Visual	3.40	4.03	4.11	5.59	5.66	7.52	5.05	4.37	5.85	6.83	8.73	9.20	12.48	7.91	6.17	8.14	8.72	10.94	9.70	11.82	9.25
Verbal	3.80	3.81	5.12	5.16	6.23	6.88	5.17	4.52	4.56	8.13	7.70	9.58	10.68	7.53	7.41	8.06	9.40	10.07	10.73	11.08	9.46
Control	4.00	4.31	4.97	4.74	6.89	6.46	5.23	5.29	5.07	8.81	7.27	10.23	13.44	8.35	7.23	7.39	10.81	9.95	11.59	10.67	9.61
Total	3.73	4.05	4.73	5.16	6.26	6.95		4.73	5.16	7.92	7.90	9.67	12.20		6.94	7.86	9.64	10.32	10.67	11.19	

NOTE: E = Element, J = Japan, US = United States

17

Table 3

Mean Number Correct on False Matrices

Grade/ Training	Sex	Zero Transformations				One Transformation				Two Transformations			
		1E	2E	3E	Mean	1E	2E	3E	Mean	1E	2E	3E	Mean
Second													
Visual	M	.90	.92	.75		.82	93	.68		.82	.82	.69	
	F	.94	.92	.90		.85	.90	.82		.92	.78	.68	
Verbal	M	.85	.89	.79		.74	.81	.64		.88	.75	.56	
	F	.72	.82	.69		.60	.81	.74		.71	.78	.57	
Control	M	.78	.83	.79		.78	.85	.71		.79	.69	.64	
	F	.82	.88	.77		.63	.83	.67		.73	.62	.58	
	Total	.835	.87	.78	.83	.735	.855	.71	.765	.805	.745	.62	.725
Fifth													
Visual	M	.96	.94	.88		.85	89	79		.97	.86	.85	
	F	.92	.99	.86		.86	.95	.76		.89	.81	.69	
Verbal	M	.93	.97	.94		.85	.90	.83		.89	.81	.78	
	F	.89	.93	.94		.79	.82	.76		.90	.78	.75	
Control	M	.98	.94	.91		.88	.88	.80		.91	.80	.74	
	F	.95	.95	.89		86	.91	.74		.94	.80	.80	
	Total	.94	.955	.905	.935	.845	.89	.785	.84	.915	.81	.77	.835
Eighth													
Visual	M	.96	1.00	.96		.97	.93	.89		1.00	.99	.92	
	F	.99	1.00	.89		1.00	.93	.78	.99	.99	.97	.88	
Verbal	M	.97	.99	.94		93	.90	.82		.93	.90	.86	
	F	.93	1.00	.89		.96	.93	.86		.97	.94	.92	
Control	M	.95	.97	.86		.94	.94	.83		.94	.92	.88	
	F	.98	1.00	.92		.95	.93	.83		.98	.93	.95	
	Total	.965	.99	.92	.96	.96	.925	835	.91	.965	.945	.90	.935

NOTE: E = Element

Table 4

False Matrices Response Times

Country/Train/Grade	Zero Transformation 1E	2E	3E	Mean	One Transformation 1E	2E	3E	Mean	Two Transformation 1E	2E	3E	Mean
JAPAN												
Visual												
2	3.82	4.87	6.25	4.98	5.19	5.06	6.69	5.65	4.77	5.96	8.02	6.25
5	3.34	4.17	4.35	3.95	4.10	3.30	4.64	4.01	3.53	4.96	5.79	4.76
8	3.13	4.38	5.39	4.30	4.93	5.13	7.56	5.87	5.10	6.70	9.75	7.18
Mean	3.43	4.47	5.33		4.74	4.50	6.30		4.47	5.87	7.85	
Verbal												
2	3.93	5.06	5.63	4.87	5.60	5.59	6.76	5.98	5.13	5.97	7.41	6.17
5	3.56	5.05	7.08	5.23	6.27	5.63	8.36	6.75	5.70	7.76	10.96	8.14
8	3.46	4.70	6.43	4.86	5.51	5.83	7.90	6.41	5.55	8.14	10.54	8.08
Mean	3.65	4.94	6.38		5.79	5.68	7.67		5.46	7.29	9.64	
Control												
2	3.94	4.71	6.41	5.02	5.34	5.38	7.14	5.95	5.62	6.50	8.08	6.73
5	3.89	4.83	7.36	5.36	5.95	5.86	8.13	6.65	6.04	8.77	11.16	8.66
8	3.29	4.58	6.69	4.85	5.45	6.54	9.00	7.00	6.41	8.77	11.69	8.96
Mean	3.71	4.71	6.82		5.58	5.93	8.09		6.02	8.01	1031	
Males	3.38	4.41	5.99	4.59	5.10	5.07	7.06	5.74	5.01	6.79	8.46	6.75
Females	3.87	4.99	6.29	5.05	5.61	5.60	7.51	6.24	5.53	7.19	9.92	7.55
UNITED STATES												
Visual												
2	4.39	6.11	9.03	6.51	6.80	7.04	9.95	7.93	7.31	9.12	11.94	9.46
5	4.37	6.00	7.34	5.90	6.09	7.33	8.51	7.31	7.14	8.54	11.62	9.10
8	3.70	5.19	8.05	5.65	5.84	7.42	1042	7.89	6.89	1002	1290	9.94
Mean	4.15	5.77	8.14		6.24	7.26	9.62		7.11	9.23	1215	
Verbal												
2	4.09	5.54	6.38	5.31	5.30	5.78	9.19	6.76	6.03	7.12	9.84	7.66
5	4.61	7.48	7.92	6.67	8.01	8.05	1009	8.72	9.02	11.73	1560	1212
8	3.68	5.28	7.08	5.35	6.00	6.19	8.86	7.02	6.11	9.76	1277	9.55
Mean	4.13	6.07	7.13		6.44	6.67	9.38		7.05	9.54	1274	
Control												
2	4.34	6.09	6.95	5.79	5.52	5.56	7.48	6.19	5.98	7.06	9.23	7.42
5	4.25	5.85	7.76	5.95	7.19	8.28	1012	8.53	7.74	9.09	1293	9.92
8	3.69	5.16	6.34	5.06	6.01	6.28	8.55	6.95	6.40	9.40	11.75	9.18
Mean	4.09	5.70	7.02		6.24	6.71	8.72		6.71	8.52	1130	
Males	4.06	5.60	7.05	5.57	6.12	6.59	8.55	7.09	6.26	8.59	1148	8.78
Females	4.20	6.11	7.85	6.05	6.52	7.22	9.95	7.90	7.69	9.83	1272	1008

NOTE: E = Element.

Table 5

Table of Means for Figural Intersection and Spatial Relations Tests

Training Group/ Grade	Spatial Relations				Figural Intersection Test			
	Pretest		Posttest		Pretest		Posttest	
	Japan	US	Japan	US	Japan	US	Japan	US
Perceptual								
2	19.33	21.83	29.75	28.08	81.00	72.08	90.67	77.00
5	32.31	33.75	47.38	44.42	128.54	123.33	127.62	132.50
8	49.08	40.08	58.83	52.75	200.83	151.33	209.33	173.75
Total	**33.54**	**31.89**	**27.66**	**32.06**	**136.57**	**115.58**	**142.14**	**127.75**
Verbal								
2	17.42	31.75	28.42	32.17	78.42	56.17	81.50	64.67
5	31.73	42.67	46.55	52.33	125.27	134.00	125.73	135.50
8	38.83	39.25	45.50	52.58	200.08	131.75	208.00	163.17
Total	**29.26**	**37.89**	**48.38**	**45.31**	**134.86**	**107.31**	**138.77**	**121.11**
Control								
2	17.09	28.27	24.55	36.27	58.91	43.73	63.09	49.36
5	36.40	35.58	51.70	39.17	139.60	99.50	143.70	115.92
8	46.30	39.73	55.00	54.45	202.60	134.73	198.80	155.09
Total	**32.74**	**34.56**	**53.00**	**53.23**	**131.29**	**92.85**	**132.87**	**106.06**

NOTE: Scores can range from 0 to 70 on the Spatial Relations and 0 to 225 on the Figural Intersection Test.

Table 6

Correlations

Grade	Ravens	FITPRE	FITPOST	SPAPRE	SPAPOST
2nd					
Ravens					
FITPRE	.39**M				
FITPOST	.36*M	.83***M			
		.83***F			
SPAPRE			.31*M		
SPAPOST				.55***M	
			.29*F	.72***F	
TTAC	.46**M		.31*M		
		.32*F			
TFAC	.43**M	.44**M	.50***M	.36*M	.40**M
		.32*F	.29*F		
5th					
Ravens					
FITPRE	.67***M				
	.42**F				
FITPOST	.67***M	.83***M			
	.49***F	.64***F			
SPAPRE	.38*M	.36*M	.40**M		
SPAPOST		.37*M	.38*M	.59***M	
	.34*F		.31*F	.54***F	
TTAC	.57***M	.61***M	.56***M	.50***M	.55***M
TFAC	.58***M	.51***M	.40**M	.34*M	.36*M
			.49***F		
8th					
Ravens					
FITPRE	.41**M				
FITPOST	.48**M	.81***M			
		.82***F			
SPAPRE	.47**M	.45**M	.34*M		
		.46**F	.34*F		
SPAPOST	.36*M	.30*M	.33*M	.70***M	
				.80***F	
TTAC	.65***M	.37*M	.38*M		
		.41**F		.39**F	
TFAC	.57***M	.39**M	.45**M	.28*M	.39**M
		.40**F	.46**F	.39*F	.31*F

NOTE: *p < .05; **p < .01; ***p < .001.
FITPRE = Figural Intersection Pretest; FITPOST = Figural Intersection Posttest
SPAPRE = Spatial Relations Pretest; SPAPOST = Spatial Relations Posttest
TTAC = Total correct on true matrices; TFAC = Total correct on false matrices
M = Male; F = Female

Figure Caption

Fig. 1 Examples of the experimental matrices. Top: A "true" matrix with two elements and zero transformations. Bottom: A "false" matrix with three elements and two transformations.

Figure 1